SCIENCE

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THE RELATION OF CHEMICAL LABORATORIES TO THE NATIONAL WELFARE[1]

FOR two years and a half the world has been in a ferment. On the basis of an incident which now seems trivial, the mutual jealousies and distrust of the nations of Europe precipitated a war in which the interests of all the nations of the world are involved. Those of us who think that our race is progressing toward better conditions can not but believe that there will grow out of this war some better method of settling differences between nations. The duel as a means of settling private quarrels has long since disappeared in England and America. It must surely cease as a means of settling quarrels between nations. It seems certain that the time will come when the world will look back to these years as a time of madness like the madness that drove men to the crusades of the middle ages.

With all the loss and waste and dreadful suffering of these years the nations of the world are learning some lessons which would not have been learned in times of peace. Russia has solved her liquor problem for the time being. Germany enforces a democratic equality in the distribution of food which is beyond the wildest dream of the socialists. Bread is distributed by cards and the wealthiest citizen can get no more than the day laborer. England has solved the problem of the unemployed—there is no longer a "submerged tenth" for whom conditions are utterly hopeless. One of my friends who has been in London with

[1] An address delivered at the dedication of the chemical laboratory of the University of Oklahoma, January 26, 1917.

his family reports that his wife was commiserating her charwoman on the suffering of the war, when the latter replied: "It's not so bad—a pun' a week and the man away from home—it's too good to last."

In America, too, we are learning some lessons—among others that our industrial independence, at least in the matter of dyes for our textiles, is of some importance.

If we try to find a single word which expresses that for which all of the warring nations are striving it is *efficiency*. It seems very dreadful that the desire to slaughter our fellow men should be the incentive, and if we did not believe that the lessons learned under the stress of war will remain during the long years of peace that are to follow, we might well wish for the good old times before scientific efficiency was thought of. But whether we will or not a new sort of efficiency has come to stay and it is worth our while, here in America, to grasp its meaning and to look for the foundation on which it has been built.

I see with the eyes of a chemist, of course, and shall draw my illustrations from the science which I know best, but much that I have to say applies to other sciences as well.

A little less than one hundred years ago, shortly after Europe had settled down from the tumult of the Napoleonic wars a young German doctor of philosophy, not yet out of his teens, went to Paris to study chemistry and succeeded in gaining admission to the private laboratory of Gay Lussac. Liebig was a born chemist, if ever there was one, and had worked with things chemical from early boyhood. But even Liebig needed the inspiration of contact with one of the master chemists of his time, and this Gay Lussac gave him. After a few months he returned to Giessen and there in a laboratory which was new of its kind in university life he gathered about him an enthusiastic group of young men who came to him for the study of chemistry. The laboratory was very crude and primitive in comparison with the palaces of science which we build to-day, but out of that laboratory went influences which have spread over the whole world—Liebig's idea of a laboratory was not that it is chiefly a place for teaching what is already known, but rather that it is a workshop where teacher and pupil are striving together to learn something new from the great book of nature. Very soon many similar laboratories sprang up and within a few years Germany became the country to which young men resorted from all over the world for the study of chemistry.

A. W. Hofmann, one of the talented young men of the Giessen group, was called to London by Prince Albert in 1845. There he taught in the college of chemistry. He employed as an honorary assistant, some years later, a young man by the name of William H. Perkin. Young Perkin became so interested in the subject that he was not content merely to work with Hofmann during the day, but he fitted up a private laboratory at home where he could work at night. Here he tried to do some experiments in the hope of obtaining a synthesis of quinine. His first experiments gave an unattractive reddish brown precipitate of the sort that most chemists would pass by as hopeless. He became interested, however, and tried similar experiments with a simpler substance, aniline. The product was at first still more unpromising, but on further examination he found that it contained a beautiful purple coloring-matter which was capable of dyeing silk and other textiles. It was in fact the substance we now know as the "Mauve dye." Perkin, then a lad of only eighteen years, conceived the daring idea that this color might be put to practical use. Fortunately his father had faith enough in his ability to

furnish him with the necessary financial assistance. It was a new thing under the sun and it is fascinating to read of the difficulties met and overcome in developing the industry of the coal-tar dyes. The benzene which is now separated from coal-tar to the amount of thousands of tons annually was not to be had as a definite product and it was necessary to invent the machinery and apparatus for carrying out on a large scale operations which, hitherto, had been tried only in test-tubes. Even when the new dye had been made, the dyers, who were accustomed only to vegetable dyes, could not use the product and Perkin had to go into their dyehouses and teach them how to handle the material. All of these difficulties were finally overcome and a successful foundation was laid for a great industry, which in less than a generation revolutionized the artistic beauty of our wearing apparel.

A few years later two German chemists solved the riddle of the structure of alizarin, the coloring matter of madder root, and showed that the dye could be made from the anthracene of coal tar. They did not, however, put the production of the material on a commercial basis and here, again, it was William H. Perkin who worked out the economic details of manufacture in his factory.

With such a beginning it would have seemed that England must be the leader in the manufacture of artificial dyes, but long before the end of the nineteenth century Great Britain had lost all her initial advantage and Germany was preeminent in the production of synthetic colors.

When we look for the reason for this surprising result we find it almost entirely in the laboratories founded on Liebig's ideal—laboratories where students learned the chemistry already known, it is true, but where, much more than that, and as their prime object, teachers and pupils gave their energies intensely and incessantly to the development of an ever-changing science. Young men trained in such an atmosphere proved to be the very ones who could solve the varied problems of an industry which is so intimately connected with investigations in pure science. In addition to the supply of trained chemists furnished by the universities there grew up a most intimate connection between the university laboratories and the factories where dyes were made. An illustration will help to make this clear. Kekulè, one of the men who worked with Liebig in Giessen, proposed his theory of the structure of benzene in 1865. This has become, perhaps, the most important single thought guiding the work of the color-chemists even to the present day. Baeyer, who had studied with Kekulè, took up, in the same year, some work on isatin, an oxidation product of indigo. He tells us with what pleasure he had spent for a piece of indigo a birthday present of two thalers, given him when he was thirteen, and with what a feeling of reverence he drew in the odor of orthonitrophenol while he was preparing isatin from it by the directions which he found in an organic chemistry.

After working upon isatin and other derivatives of indigo for four years with good success Professor Baeyer dropped the subject for eight years because his former teacher Kekulè published a paper in which he announced that he was attempting a synthesis of isatin. It was evident that Kekulè did not succeed and in 1877 Baeyer felt justified in taking up the subject again. Three years later he discovered a synthesis of indigo which was of sufficient promise for a patent and the Badische Anilin Soda Fabrik began at once an attempt to put the synthesis on a manufacturing basis. But a successful synthesis in the laboratory is very different from successful production in a factory. The chemists of the factory worked over the process from every pos-

sible point of view for fifteen years. The various steps in the process were greatly improved and more than a hundred patents were taken out, but it was never possible to convert Baeyer's synthesis into a successful manufacture of indigo on a large scale. The original material required for that synthesis is the toluene of coal tar and the annual production of this substance would be sufficient to produce only about one fourth of the indigo required in the world. As toluene is used in the manufacture of a great variety of other dyes and compounds it is evident that any considerable use for the manufacture of indigo would cause such an increase in price as automatically to stop the manufacture. No manufacture of indigo could succeed unless the dye were made at a price to compete with the agricultural production in India.

The factory found its way out of this *cul-de-sac* by means of a discovery made by Professor Heumann in the chemical laboratory of the Polytechnic at Zurich, Switzerland—a laboratory which has given us many brilliant discoveries in chemistry and which is conducted on a high scientific plane, not on the theory that it must devote itself to so-called practical problems. By combining Heumann's discovery with another made by Hoogewerf and van Dorp in a laboratory in Holland it became possible to manufacture indigo with naphthalene of coal tar as the starting-point. Naphthalene, known to us all in the familiar moth balls, is abundant and cheap.

Even with the aid of these fundamental discoveries from the university laboratories the chemists of the factory worked incessantly upon the problem for seven years before they felt sufficiently sure of their ground to recommend the building of a plant for the manufacture on a large scale. Two incidents of the development are of sufficient interest to deserve mention. The first step in the process is the oxidation of naphthalene to phthalic acid. The processes which had been used before that were too tedious and expensive. In the course of a systematic examination of all possible methods for cheapening the process a chemist accidentally broke a thermometer in a mixture of naphthalene and sulfuric acid which he was heating. The mercuric sulfate which was formed proved to be the needed catalyst to hasten the reaction and the details of a successful process for the oxidation were soon developed. But, as is so often the case, the solution of one problem brought out a second difficulty. Strong sulfuric acid is required for the oxidation and this is reduced to sulfur dioxide, which it is necessary to recover and convert back into the strong acid by oxidation with air. This led to the transformation of the old and well-known contact process for the manufacture of sulfuric acid into a new and radically changed form. Incidentally it may be remarked that the new contact process soon found its way to America and has been used to convert to sulfuric acid the sulfur dioxide obtained as the first step in the reduction of zinc ores. The strong sulfuric acid has been used, in turn, in making dynamite.

Finally, in July, 1897, the preliminary work was completed and the Badische Anilin Soda Fabrik was ready to begin the construction of the necessary factories. In October, 1900, Dr. Brunck reported that the firm had spent about eighteen million marks or four and a half million dollars upon their plant and that the production had already attained a proportion which corresponded with the natural production from 100,000 hectares or nearly 250,000 acres of land. In reply to the suggestion that the competition might prove disastrous to the farmers of India he expressed the hope that the land now used for the production of indigo may be released for rais-

ing food stuffs, often sorely needed during the famines in that country.

It has seemed worth while to consider this development of the manufacture of indigo in detail because it points out so clearly the road which we must travel in America if we are to succeed in the color industry. It is a lesson which American manufacturers are learning, too, and this promises well for the future. A manufacturer in Michigan has recently taken a promising research worker in organic chemistry from the University of Michigan to help him develop the manufacture of indigo, and another manufacturer in Buffalo last summer called a man from the University of Illinois at twice the salary he was paid there, to organize a research laboratory for the manufacture of dyes. In each case the man secured his training in the research work of a university laboratory.

At the beginning of the war we were using dyes in the United States to the value of about $15,000,000 a year. Of this amount only about $3,000,000 worth were made in America. Nearly all the rest came from Germany. Textile industries having a product worth hundreds of millions are directly dependent on dyes and there is scarcely a person in this country who has not seen in some form the effect of the shortage. The dye manufacturers have been alive to the situation and in another year they will be able to furnish the quantity of dyes required, though they will not be able to furnish as great a variety as were formerly used.

We have heard a good deal, in recent years, about a scientific tariff commission. The action of Congress last summer illustrates the need of such a commission. The importance of making ourselves independent of other countries had become so evident that a bill was introduced providing for an *ad valorem* tax on dyes of 30 per cent. and a specific tax of 5 cents per pound. The specific tax is to continue for five years. At the end of that time it is to be decreased one cent a year till it disappears. There is also a provision that if the American factories do not produce 60 per cent. of the value of our home consumption at the end of five years the specific duties are to be completely repealed. While the specific duty is only two thirds of the amount which had been recommended by the New York Section of the American Chemical Society, it might, perhaps, have been sufficient if it were not for another provision which was allowed to creep in. Apparently at the instigation of some large user of dyes, indigo, alizarin and their derivatives were excluded from the specific duties. No logical reason, whatever, can be given for this exclusion. It must be due either to stupidity or to an attempt to favor some special interests. As this class of dyes constitutes 29 per cent. of the whole and at least 10 per cent. of the other dyes are covered by foreign patents, it is evident that the hope that our factories will produce 60 per cent. of our dyes in normal conditions of foregin competition is small.

Still other difficulties beset the industry. The manufacturers of dyes in Germany have very definite arrangements by which one dye is made by one firm, another by a second, and still another by a third so that there is no real competition in the manufacture of staple products. Such combinations are fostered rather than hindered by the German government, but similar combinations in this country are forbidden by the Sherman law. The way out of this difficulty seems to be in the first place a census of dyes showing what dyes are used and the quantities of each. Such a census has already been prepared by the expert of the Department of Commerce and Labor. If we can combine with this, in accordance with a suggestion of Dr. Herty, the editor of our *Journal of Industrial and Engineer-*

ing Chemistry, a frank statement by manufacturers, of the dyes which they intend to make, we may find a solution of this problem which is in accord with the democratic equality of opportunity which the Sherman law is designed to conserve.

The greatest fear of the manufacturers is that after the war they may be subjected to an unfair competition designed to destroy the new industry. The following story was told during a discussion of the dyestuff situation which was held in New York in September. Mr. Dow, of Midland, Michigan, discovered a good many years ago that the salt brines of Michigan contain enough bromine so that the element can be economically produced, and in the course of a few years he developed the manufacture to such a point that he shipped some bromine to Germany. Not long after a German appeared at his works in Midland and said to him: "I have conclusive evidence that you have been selling your bromine in Germany. Didn't you know that you can't do that?" Mr. Dow replied that he knew of no law against it. The German said "Well you can not. If you do, we will sell two pounds of bromine in America for every pound you sell in Germany." Mr. Dow paid no attention to the threat but went on with the production of bromine. Some months later when he was in Texas on business he received a telegram "Bromine is selling at 15 cents." A normal price is 75 cents. Mr. Dow closed his story at this point. The representative of the German Kali-Industrie, who was present, got up and asked him: "Well, wasn't it satisfactorly adjusted?" But he made no reply. I am fortunate enough to have heard the rest of the story—which is known to a good many outsiders, so I am betraying no confidence in telling you. Mr. Dow stopped selling bromine in America and sent his whole product to Germany. It was not long before the German manufacturers were ready to come to terms. Before the war Germany was manufacturing three fourths of the coal-tar dyes used in the world and we may be sure that she will not easily relinquish her position of preeminence in this field. Her manufacturers will surely attempt to destroy our manufacture of dyes by the same methods which were used to stop the manufacture of bromine—by the so-called "dumping" of materials here at prices below the cost of production. Laws have been passed by Congress imposing severe penalties for such practises, but some of our manufacturers are very sceptical as to their efficiency. We are not in as favorable a position to compete in the making of dyes as Mr. Dow was for the production of bromine.

I think it is clear from what has been said that the manufacture of dyes rests at its foundation upon the research work done in the chemical laboratories of the German universities and that we may trace it back very directly to the days when Liebig returned from France with the inspiration which came from Gay Lussac, and founded the laboratory in Giessen. One of the most important factors in the dreadful efficiency of Germany during the last three years may be traced back to the same source. Not a few of our leading men have emphasized the advantage of developing the dyestuff industry in America because the men trained in this industry will be most competent to handle the manufacture of explosives in case of war. Personally I have a strong hope that at the close of the war the world will be organized on the basis of justice instead of force, but for the present we can not ignore such arguments.

I wish to congratulate you on the completion of this laboratory at a most opportune time. We are in the midst of a very rapid development of our chemical industries. New lines of manufacture are being established and old lines are being rapidly developed. Manufacturers realize as they

have never done before how much chemistry can contribute to their success.

At the risk of seeming personal I will give a few illustrations of how chemical research in a single laboratory has demonstrated its value under American conditions.

A young man graduated from the course in chemical engineering at the University of Illinois in 1910. Soon after he was employed by a manufacturer of cement in the state of Washington. Something had gone wrong in the factory and hundreds of barrels of cement were rejected because the material did not meet the specifications. The young graduate, trained in methods of research, soon found the cause of the difficulty and corrected it and the firm has continued in the successful manufacture ever since.

In 1907 a graduate of Worcester Polytechnic Institute who had spent one year at the Massachusetts Institute of Technology came to Illinois as a research assistant. He completed his work for the degree of Ph.D. three years later and was continued as an instructor and later became assistant professor in charge of the division of organic chemistry. In 1916 one of the oldest of the firms manufacturing dyes in America searched the country over to find a man to organize their research laboratory. They selected this man, not because of any experience which he had had in industrial work, but because of his record as a research worker in pure organic chemistry and because of his ability to apply the principles of physical chemistry to this field.

Another young man, a graduate of Oberlin College and trained in research by Edgar F. Smith, of the University of Pennsylvania, came to Illinois in a subordinate position in 1907. During the eight or nine years following he became one of the leading workers in this country in researches upon the rare earths, and he was gradually advanced to the position of professor of inorganic chemistry. Two or three years ago he was asked by a firm in Chicago to assist them in the details of an important application of tungsten to an industrial use. He solved the problem and the result proved to be of large commercial value. Last year he was asked by the firm to organize a research laboratory to study the application of rare metals to industrial uses.

Another chemist who graduated at Illinois and afterwards took his degree of Ph.D. at Wisconsin is now state food commissioner of Illinois. There is not a man, woman or child in the state of Illinois who is not directly or indirectly dependent on this chemist for the maintenance of proper standards for the food which he eats.

Many similar illustrations of the importance of trained chemists might be given by any large university in America.

Such a laboratory as this has three important functions to perform. It must give an elementary knowledge of chemistry to many students who will not become chemists, but who yet should study the subject because chemistry touches the life of every one at many points. But this part of the work will be very poorly done if it merely imparts a set of so-called practical facts about every day life. Such facts will be quickly forgotten, but chemistry, better than almost any other science, furnishes a basis for clear scientific thinking and for students to acquire the habit of reasoning from one point to another in such a manner as to connect and combine their knowledge into a coherent, logical system. The discipline acquired in this way is of greater value than any set of facts that may be learned.

In the second place the laboratory will train a few men who will find their way into chemistry as a profession—it may be into some of the industries to which I have referred, or to become teachers, or to work

in our experiment stations over the important applications of chemistry to agriculture.

The third and most important function of the laboratory is the contribution which it makes to the growth of our science. Here in Oklahoma you have many problems which can be solved with the aid of chemistry. But just as Germany would have failed utterly to reach her highest achievements if her university professors had confined themselves to so-called practical problems, so this or any other university will fail if its staff does not devote a considerable part of its energies to the advancement of the science of chemistry quite irrespective of whether industrial applications for the results of their researches are apparent or not. No chemical laboratory has a right to call itself a university laboratory if it loses sight of this, the highest of its functions. A high-school may devote itself exclusively to teaching and a college may possibly do the same, though of that there is serious question. For the university there can be no question. Ours is a vital, growing, rapidly changing science and only those who are intensely interested in its growth can properly teach and inspire those who are to go out into the world and use for the advantage of themselves and of the state the training they gain in university halls.

William A. Noyes

MILITARY GEOLOGY

Modern warfare is a science, or rather an application of many sciences, and therefore it can afford to neglect no scientific field the cultivation of which would make for added superiority, in however slight degree. The usefulness of certain sciences to the carrying on of war is obvious or has been made so by the conditions of the European contest: such are surgery and chemistry; the military application of certain other sciences, however, is not so apparent and needs to be pointed out from within the subject itself: thus it is with geology. If the service that this science can render to the country in time of war be clearly established, then it follows that geology will be incorporated in our plan of military development and be called upon to do its proper part in furthering the military effectiveness of the nation.

This is a new rôle for geology, but a rôle already played and established in the theater of war in Europe. Military geology is a phase of applied science that has served the warring nations abroad; it sees many duties that it may perform for the United States.

In the first place, geological knowledge may be employed to advantage by an army in the field. "What a Geologist Can Do in War," is the title of a brochure prepared by R. A. F. Penrose, Jr., for the geological committee of the National Research Council and published in April, 1917. This short essay in scarcely more than a thousand words specifies clearly the varied service that a knowledge of geology can render, not only to the army in camp, but to the army on the march and in battle. The importance of this service may be judged by observing some of the problems arising in the course of field operations, which the geologist might appropriately be expected to solve.

The selection of camp-sites involves problems in drainage and sanitary arrangements, which become more difficult of solution in marshy country; in arid regions the possibility of disastrous cloudbursts destroying camps improperly located demands attention. Trenches and tunnels must be placed, so far as strategic conditions allow, in easily workable and drainable rock formations; while the stability of slopes depends upon the material in which the excavations are made. Ground for artillery positions should be selected not only from topographic considerations, but also in respect to the firmness and elasticity of the underlying rock, upon which the accuracy of fire will in part depend. The construction or repair of roads is a frequent military need, the more important because of the nec-